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LT and LRT

Many years ago a railway signal engineer foresaw the day when ‘the signals will drive the trains’. Today the forecast has been brought close to reality on the Victoria Line of London Transport. Experiments with automatic train operation were begun by London Transport as long ago as April 1962, when trials took place between Acton and South Ealing. A passenger train with prototype equipment went into service between two District Line stations a year later, and in April 1964 London Transport inaugurated a complete service of automatic trains between Hainault and Woodford. The system used was the one later installed on the Victoria Line, opened throughout between Walthamstow Central and Brixton in 1971.

Automatic acceleration is a familiar aspect of EMU working, and once the process has been initiated the train will attain balancing speed without further action. In the simplest possible arrangement, it would then only be necessary to switch off power at a selected point before the next station and thereafter control braking to a standstill. The Victoria Line system performs these and other control functions in two ways. Certain ‘safety’ information is conveyed to the train continuously by inductive pick-up of the currents in the signalling track circuits, which are in the form of pulses occurring at various rates per minute according to the instruction to be given. Other instructions, such as to stop between stations, begin coasting, and regulate speed down to a standstill by braking, are given by audio-frequency currents applied to the track at specific points called ‘command spots’.

Automatic driving cannot take place unless one of the safety codes is being picked up from the track. A code of 420 pulses/min allows a train to start from a station and accelerate to full speed after the driver (or ‘train attendant’) has pressed two pushbuttons simultaneously to show that doors are closed, and it is safe to depart. While the train is in motion the code may change to 180 pulses/min, which initiates coasting and controls the brakes so that speed does not exceed 22mile/h. If a signal is at ‘danger’, a command spot a suitable distance ahead will be energised and the braking increased to bring the train to a standstill. When the signal clears the track code changes to 270 pulses/min, which restarts the train automatically. While this pulse rate is maintained the train is restricted to 22mile/h, alternately motoring and coasting as necessary. Restoration of the 420 code allows acceleration to full speed.

Stopping in a station is controlled by a sequence of ‘spots’, the first switching off the motors so that the train coasts and the remainder transmitting frequencies proportional to the speed at which the train should be travelling at each point in order to stop accurately in the platform. Actual speed is compared with the ‘command’ speed and the braking adjusted accordingly.

Fully automatic working is now known as automatic train control (ATC) – a term and initials formerly applied to a signalling practice. The London Transport system is not full ATC because the driver controls the doors and the length of the stop at stations (the ‘start and accelerate’ code is not effective until he has pressed his pushbuttons). Strictly speaking it is a combination of two ATC sub-systems – ATP (automatic train protection, i.e., the control frequencies continuously present in the track) and ATO (automatic train operation, i.e., the functions of the ‘command spots’).

Since the new trains for the extension of the Metropolitan Line electrification to Amersham in 1960, London Transport has been using 300V traction motors connected in series pairs. The practice is continued in the 1973 tube stock, (which actually appeared in 1976). From the new trains for the Victoria Line onwards, all LT stock has been equipped with rheostatic braking, and in the 1973 stock motorcoaches the resistors are forced-ventilated by a motor-blower combined with the motor-alternator auxiliary supply set. A six-car train of this stock consists of two three-car units with their cars semi-permanently coupled. The unit formation of motorcoach, trailer, and non-driving motorcoaches provides 8 motored axles out of 12, or two-thirds motored

Above: Prototype Metrocar for the Tyne and Wear Metro on the test track at Middle Engine Lane in 1978./*I. S. Carr*

axles per train compared with half in other recent tube stock. The traction equipment has been redesigned to use a single camshaft in place of the two carried by earlier motorcoaches with rheostatic braking. There are three weak-field steps, which are used in starting as well as at the top of the speed range. The train starts in weakest field with all resistance in series and full-field is only attained on the fourth of the 20 motoring notches – a procedure known as 'soft notch' starting. It sounds a refinement, but in a service with large numbers of standing passengers often dependent on each other for maintaining the perpendicular the smooth start is probably appreciated.

London Transport began work with chopper control in 1965 and has operated two four-car trains with this type of equipment on the Woodford-Hainault branch to test the effect on signalling equipment. New prototype chopper equipment being commissioned in 1978 incorporated rheostatic/regenerative braking with automatic changeover between the two modes so that energy can be returned to the line whenever conditions permit. In LT conditions chopper control is only considered economic if associated with energy saving by regeneration. It has other advantages, however, such as fewer moving parts, quicker response to different conditions of loading, and improved line current regulation because the large peaks associated with resistance control are absent. In the latest LT equipment, the chopper occupies most of the car underframe and the chopper case itself is force ventilated. The capsule type thyristors are cooled on both faces by being mounted between heat sinks.

Offsetting the advantages of the regenerative chopper are the constraints imposed on timetabling to ensure that trains are in proximity to each other to absorb regenerated power, and extra switchgear required for a modified system of substation inter-connection. For these reasons the LTE is also studying energy storage by flywheel as a long-term possibility and is developing a scheme based in principle on the flywheel booster circuit of the three original Southern Co-Co locomotives. It is estimated that a 25% energy saving could be achieved with accelerating and braking characteristics distinctly better than with other methods of control. There are problems at present, however, in high noise level and the very high reliability requirements set by the Department of the Environment if flywheels revolving at some 10,000rev/min are to be installed in passenger carrying vehicles.

City railway operations such as those of London Transport have long been described as 'rapid transit'. More recently the term 'light rapid transit' (LRT) has come into use to describe systems in which the vehicles are often of the articulated tramcar style long familiar on the Continent and run on reserved tracks above ground in outer areas but enter tunnel sections with underground stations in city centres. The first example of such a system in Great Britain is on Tyneside.

Two British Rail electrified services had been based on Newcastle Central station. One was the North Tyne Loop via the coast to West Monkseaton and back to Newcastle via South Gosforth and Jesmond; the other was the line south of the river through Gateshead to South Shields. The last electric trains ran in 1967 but services were maintained to West Monkseaton and to South Shields by diesel multiple units.

A detailed study of the North Tyne Loop was undertaken by the Tyneside PTE, this being the busier of the two lines and also the one with the largest deficit. Various alternatives were examined, including conversion of much of the Loop into a bus way. The conclusion was reached, however, that the transport needs of the area would be best met by developing an integrated rail/road system with Light Rapid Transit over the existing suburban rail routes north and south of the Tyne as its backbone. A grant was obtained under the terms of the 1968 Act and in 1972 the Tyneside Metropolitan Railway Bill was presented to Parliament, receiving the Royal Assent in the following year. This was the beginning of the Tyne and Wear Metro, so named because the PTE had become the Tyne and Wear PTE upon local government reorganisation in 1974.

The rail operations of the Metro were not planned simply to run over former BR tracks. Newcastle Central station may have been appropriately named in the past, but the city has spread northwards away from the River Tyne so that the station is now at one end of it, and the BR rail routes lie to the east of the central area. The Metro has therefore built two lines totalling 6.4km (4 miles) in tunnel under the centre of the city. The North-South line leaves the BR lines immediately north of Jesmond station and passes under the central city area in twin tunnels with new underground stations at Jesmond, Haymarket, Monument, Central Station, and Gateshead. The line makes a short but impressive reappearance between two tunnel sections to cross the Tyne on a bridge with a span of 164.5m (540ft), the longest span on the river and a noteworthy addition to the panorama of bridges seen by the traveller arriving at Newcastle by rail from the South. After Gateshead underground station the line finally surfaces at Old Fold and joins the former South Tyne electrified line to South Shields, but after Tyne Dock it follows a new alignment to South Shields via Chichester (the first syllable here rhymes with ‘pie’), which is the focus of the local bus system. It has been Metro policy to bring public transport where it is needed today. Another example is at Byker where a high-density housing area has developed away from the old station and a new alignment has been followed to provide it and the adjacent shopping area with a conveniently sited station.

The West-East line starts underground in a new terminal at St James and runs via Monument (interchange with the North-South line) and a new underground station at Manors before surfacing to cross the Ouseburn valley on a new viaduct to Byker. The North Tyne Loop is joined west of Walkergate BR station, the route continuing round the coast, through South Gosforth and southward to join the North-South underground line at Jesmond. The whole system comprises 12.8 route-km (8 route-miles) of new construction and 41 route-km (25 route-miles) of existing railway, but where existing tracks are used the Metro and BR services operate as separate systems. The two administrations collaborated in various engineering works to preserve separation, and common user of tracks is confined to a section with a minimal BR freight service where part of the former Ponteland branch from South Gosforth has been rebuilt to serve the Regent Centre Interchange and new development extending to Kenton Bank Foot. Regent Centre is one of several Interchanges laid out for easy exchange between road travel by public or private transport and rail. Bus services will be rerouted to serve the Interchanges and surrounding areas, bringing a useful reduction of road traffic in the city centre, and BR/Metro exchange stations will enable many travellers to reach their destinations without using surface road transport.

In planning the Metro consideration was given to using a third rail supply at about 750V, but local climatic and other conditions would have made a protected rail necessary, and this would have brought clearance problems. Moreover, the Chief Inspecting Officer of Railways ruled that an unprotected third rail is only permissible as an extension to an existing system, and the Tyneside lines which had used third rail were no longer electrified. Finally, the 1,500V DC system with overhead supply was chosen after a detailed study of the electrical requirements of the whole project and cost comparisons with overhead supplies at 1,000 and 750V DC. The eight substations required at 1,500V are just over half the number that would have been necessary at 750V and there was a considerable saving in capital costs. Comparing energy consumption at 1,000 and 1,500V on a typical station-to-station section it was shown that there was a saving of 9% with the higher voltage and, of course, there was the practical advantage of using a standard system.

Traction and passenger substations in the central area are fed by two 11kV ring main circuits supplied from a Metro primary substation fed at 33kV from the North Eastern Electricity Board bulk supply point at South Gosforth. In the outer area careful study of the local power supply situation enabled the traction substations to be sited close enough to supply points for them to be fed direct. The feeder cables are of cross-link polythene with copper conductors and a copper tape screen. This form of solid dielectric cable can operate at higher temperatures than cables of similar cross-section of older types and does not have the same problem of voids forming with expansion and contraction under changing load conditions. In this respect its qualities are similar to those of oil-filled cables, but without the complication of reservoirs and pressure-monitoring arrangements.

The six outer area substations are designed to have a capacity of 2MW, and South Gosforth, Byker and Old

Fold have 4.5MW installations. There is provision at South Gosforth for a further 1.5 MW. The electrical system was planned as a whole, supplies for services at the underground stations and 415V signalling supplies being incorporated in the traction substation installations. The whole scheme was tested by computer. Comparative studies have shown the cost to be below that of what is believed to be the cheapest comparable existing supply system.

The remote supervisory control system at South Gosforth is computer based. The power network for traction and other services is shown in outline on a panel diagram, which is normally dark but signals a change of state, such as a circuit-breaker trip, with a flashing light at the appropriate position. Controls are transmitted from a keyboard on the operator's desk, and he can call up a fully detailed diagram of any substation area for presentation on a visual display unit. This shows all the switchgear, isolators, etc which may have to be operated from the control room or by staff on the spot under the operator's instructions in dealing with an incident.

The catenary and contact wire in the overhead system are both of copper, providing the required conductivity with a contact wire of the same cross-section as in BR 25kV electrification, with which many of the fittings are common. Special efforts were made to design a system that would be unobtrusive. Simple catenary with cantilever supports is used on open-line sections. Through stations the contact wires are supported directly from span-wires on poles at 40m (131ft) spacing. Where, as in these places and through the underground tunnels, there is no catenary, there are two contact wires over each track so that the copper cross-section remains the same.

Porcelain insulators, perhaps the most obtrusive items of lineside cantilevers, have been replaced by a new type of glass fibre rod insulator only 90mm (3½in) in overall diameter and 380mm (15in) long, with a cover of irradiated silicone rubber protecting the rod and its end fittings. This insulator has withstood severe impact tests and the rubber has a self-sealing quality which gives maximum protection of the rod against all kinds of damage.

The policy in equipping the whole system has been to use proven items wherever possible. In designing rolling stock for the first transport service of its kind in this country, some features were based on Continental

practice and experience. The Metro vehicle is an articulated car 27.8m (91.2ft) long overall carried on three bogies, each outer bogie being powered by one 185kW (248hp) motor driving both axles. The motors are mounted longitudinally and each drives both axles of its bogie through right-angle gearboxes bolted to each end of the motor frame. Transmission is by quill drives through couplings incorporating rubber rings fitted between discs on the quill shafts and on the axles.

Seats are provided in the car for 84 passengers; over 200 can be carried in crush load conditions but normal peak-hour loads average about 160 per car. The cars can operate singly or in sets of up to three under multiple-unit control from the leading vehicle. Ample provision has been made in the design for short-distance urban travel requirements, with space for prams, push-chairs and luggage in the wide bays at the entrances and over the articulation bogie. Noise levels are low, the vehicles having air secondary suspension, chevron rubber primary suspension between bogie frames and axle boxes, and resilient wheels. The plug type doors are positively sealed all round when closed and leave maximum free space inside the car. Doors are released by the driver and can then be opened by passenger pushbuttons. They are closed by the driver.

With the type of traction motor installed in the cars the required operating characteristic is obtained with the two machines in each vehicle permanently in series during motoring. The three continuous running steps are full-field, inter-field, and weak-field, and there is the usual shunting notch with all resistance in series. The motors have compensating windings to maintain good commutation in conditions of low-field strength and operate at 48% and 25% of full-field in the intermediate and weak-field notches respectively. Both these running notches are preceded by an introductory step of field weakening.

For rheostatic braking the motors are connected in a conventional figure-of-eight circuit with the fields cross-connected for self-excitation (Chapter 11). Notching is by a camshaft operated by an air/oil engine similar to the type fitted in Southern Region stock since the Kent Coast electrification and described in Chapter 7. There are separate resistance banks for acceleration and braking, with the accelerating resistors and a small section of braking resistance under one half of the vehicle, the rest of the braking bank being under the other. This distribution helps to equalise the return of waste heat from the resistances to the interior of the car when the temperature requires it. Air is blown over the resistances by fans running on the 415V three-phase auxiliary system and can be ducted into the car mixed with cold air to produce the required temperature under the control of thermostats. When waste heat recovery is not required, the circuit can be reversed, and air drawn out of the car and discharged underneath it.

Maximum service speed is 80km/h (50mile/h). Resistance notching is controlled by a static relay to give an initial acceleration of 1m/sec^2 up to about 4okm/h, which is maintained by load weighing control. Maximum service braking produces a retardation of 1.3m/sec^2; use of the magnetic track brakes increases this value to over 2.3m/sec^2.

Many features of the stock are in line with current main line practice which is described elsewhere in this book and others are likely to be seen more widely in future, such as the combination of power and braking control in one handle, which is moved forward to accelerate and backwards to brake the train. Four service braking rates plus emergency braking can be selected. Disc brakes are fitted to all axles but during service braking only the rheostatic brake acts on the motor bogie axles down to a speed of 15-20km/h (9-12mile/h). Below that speed the two disc brakes on each motor bogie operate in addition to the four discs on the centre bogie which are operative throughout. For an emergency application the rheostatic brake is cut out and air braking is applied to all axles, supplemented by two magnetic track brakes on each bogie which are energised from a battery to make them independent of the air supply. A further safety feature is that the air brakes are applied by springs, the air pressure acting against them and being reduced to increase the braking effort so that loss of air supply would result in a full application. This arrangement also enable the discs to act as a parking brake.

Wheel slip and slide control is based on measurement of axle speeds by probes in proximity to toothed wheels on the axles acting in conjunction with electronic counting and comparator circuits. Wheel slide during braking is detected by a ‘rate of change of speed’ circuit and by comparison of axle speeds which in case of deviation from normal conditions releases the air brakes and halts camshaft progression on the half-car affected until the slide stops.

Scharfenberg and BSI automatic couplers were evaluated on the Metro’s test track in the prototype vehicles and the somewhat simpler BSI type was found to be adequate for Metro requirements. Pantographs are of British manufacture.

Left: Driving position in a Metrocar. The driver’s hand is on the controller, which is pushed forward to accelerate and pulled back to brake the train.
/*Crown copyright, Department of Industry*

With the development of track/train communication, motive power can no longer be considered isolation from in complete the system on which it runs. The Metro trains carry Vetag positive train identification (PTI) equipment for passing information to a trackside unit via a tuned loop mounted between the rails/. The driver can set up various information in coded form, including train number and destination. A passive transponder is carried on the vehicle and when interrogated transmits the information, which is used to operate platform indicators, to select routes through the route relay interlocking equipment, and to provide train descriptions on the control centre mimic diagram. The PTE had already been Operating UHF radio link a two-way for communication with buses and this will be duplicated between the Metro Control centre and the trains, and between control and operations supervisors, station supervisors and maintenance staff. The trains are equipped for public address from the driver's cab and by means of the radio link the control centre can speak direct to passengers. The system is arranged so that conversations on the radio link are as secure as on an ordinary telephone, being inaudible except to the two correspondents.

Ordinary lineside signalling is by automatic two-aspect colour-lights and all lines on which passenger trains operate are track-circuited. Level crossings are without gates or barriers but protection by flashing lights is planned. The crossings at Howdon-on-Tyne and Coxlodge are at station locations. Here the platforms are 'staggered' on each side of the road and the road is not closed to road traffic until a train has come to rest at a platform, when the warnings are initiated

automatically. Train stops will give protection if a signal is passed at danger and the track brakes can stop the train very quickly.

Closed circuit television is used for station surveillance and for showing drivers at stations when the train doors are clear and can be closed. The driver's position is on the left, so that he could not see the doors in use at island platforms underground or at certain open-air stations without leaving his seat. Cameras on the platforms are therefore linked with monitors on the left-hand side of the track where they can be clearly seen from the driving position.

On the Continent tramways had been put underground in cities such as Frankfurt in the 1960s, but we had dispensed with our tramways by the time the Tyne and Wear scheme was planned. The task has been to convert an under-used suburban railway into a system of a kind that will make this country familiar with benefits that Continental cities have enjoyed for many years. Whatever opinions may be held about past attitudes to light rail city transport, history did at least create a situation which enabled the Tyne and Wear Metro to start with a clean sheet and access to technical advances which were not available to the pioneers of LRT.

Below: The first production Metrocar at South Gosforth car sheds after delivery./*Tyne and Wear Transport*